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Energy Procedia 5 (2011) 1697–1705

Energy Procedia

IACEED2010

Measurable Indicators of Low-Carbon Economy for Air Transportation -A Case Study of Shenzhen

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Abstract

Because of climate change and the popularity of air travel, the issue of low-carbon economy of air transportation industry is no longer ignorable. However, there is no standard measurable indicator to evaluate low-carbon economy, especially for air transportation industry. To fill in the blank of this area, this paper firstly discusses general indicators of low-carbon economy for air transportation industry. Secondly, it explores measurable indicators to assess the level of low-carbon aviation based on generally published data. Finally, it takes Shenzhen aviation as a case to discuss the evaluation of its low-carbon economy with the established measurable indicators. This paper not only provides indicators for low-carbon economy of air transportation with practical measurement effectiveness, but also opens up a new direction for the study of low-carbon air transportation.

Selection and peer-review under responsibility of RIUDS

Keywords: low-carbon economy; air transportation; general indicators; measurable indicators; Shenzhen aviation

1. Introduction

In the context of climate change, low-carbon economy is a new research subject. Because of the popularity of air travel, the issue of low-carbon economy of air transportation industry should not be ignored. However, although Pan, Zhuang, Zheng, etc (2009) addressed the problem of evaluation methodology of low carbon city, there is no standard measurable indicator to evaluate low-carbon economy, especially for air transportation industry.

Aiming at filling the blank area of low carbon economy for air transportation, this paper firstly discusses general indicators of low-carbon economy for air transportation industry, including the level of

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1876–6102
doi:10.1016/j.egypro.2011.03.289

carbon emission per capita/mile, the level of ton-km carbon emission, carbon productivity, carbon intensity of energy, elasticity of carbon emission and aircraft capacity or aircraft load. Secondly, it explores some measurable indicators to assess the level of low carbon aviation based on generally published data. These measurable indicators are Measurable Economic Indicator (MEI), Measurable Carbon Emission Indicator (MCEI), Measurable Carbon Productivity Indicator (MCPI), and Measurable Elasticity of Carbon Emission Indicator (MECEI). Besides, the paper presents some indirect estimation methodologies to estimate the indicators with available data. Finally, it takes Shenzhen aviation as a case to discuss the evaluation of its low-carbon economy with the established measurable indicators.

This paper not only provides indicators for low-carbon economy of air transportation with practical measurement effectiveness, but also discusses the issue from a new perspective and opens up a new direction for the study of low-carbon air transportation.

2. General Indicators of Low-Carbon Economy for Air Transportation Industry

According to international low-carbon economy and ways of defining the concept, the indicators system, for measuring development of a low carbon economy or industry, should include the following factors: the level of carbon emission per capita, carbon productivity, indicator of technical standard carbon emission, indicator of energy consumption structure, elasticity of carbon emission. However, civil air transportation industry, compared with other industries, has its own characteristics, so the evaluation system of low-carbon economy for air transportation should take into account the following aspects:

- 1.The Level of Carbon Emission Per Capita/Mile

The level of carbon emission per capita/mile fairly evaluates the issue of low-carbon economy. Though similar to the level of carbon emission per capita, the level of carbon emission per capita/mile has the characteristics associated with aviation economy. It reflects the unit emission levels of carbon carrying capacity.

- 2. The Level of Ton-Km Carbon Emission

The level of Ton-Km carbon emission is similar to the level of carbon emission per capita/mile. The latter is an indicator of unit carbon emission related to passenger transportation, and is based on passenger throughput. The former is an indicator of unit carbon emission related to cargo transportation, and is based on cargo and mail throughput.

- 3. Carbon Productivity

The level of carbon productivity is the GDP creation of unit carbon emission. Carbon productivity is the inverse of carbon emission per unit GDP. It is generally used to measure the efficiency of an industry with carbon emission. Carbon productivity depends on two indicators: GDP and carbon emission.

- 4. Carbon Intensity of Energy

Carbon intensity of energy refers to the carbon emission factor of unit energy consumption. It reflects an industry's energy consumption structure. In the areas of air transportation, the carbon intensity of energy can be expressed as carbon emission per unit fuel consumption.

- 5. Elasticity of Carbon Emission

In the study of aviation economics, the elasticity of carbon emission means the ratio of carbon emission growth over revenue growth in aviation industry. Since the goal of low-carbon economy is high development with low carbon emission, the elasticity of carbon emission mainly involves the extent of carbon emission growth compared to the revenue growth, with the premise that the revenue growth is positive.

- 6. Aircraft Capacity or Aircraft Load

Different from indicators of low-carbon economy in other industries, aircraft capacity or aircraft load is a special indicator of low-carbon economy in air transportation industry. It reflects the efficiency of air transportation. The higher the efficiency, the higher the level of energy utilization will be. As a consequence, aircraft capacity or aircraft load can be regarded as an auxiliary indicator for measuring low carbon economy for air transportation industry.

3. Measurable Indicators of Low-Carbon Economy of Air Transportation Industry

Since corresponding public data is limited, it is difficult to use the above-mentioned indicators to do the actual evaluation. For example, carbon emission data and fuel consumption data of air transportation are not published. This decreases the effectiveness of evaluation on the low-carbon economy for air transportation. However, based on available published data, we can explore measurable indicators to replace the above-mentioned ones, and thus implement the measurement.

The data related to public transportation mainly include passenger throughput, cargo throughput, number of aircraft movements. Passenger throughput refers to passenger numbers by water and air into and out of port range during the reporting period. Cargo throughput refers to cargo and mail weight by water and air into and out of port range during the reporting period. Number of aircraft movements refers to the number of aircraft into and out of port range during the reporting period.

Suppose during the reporting period, the airport passenger throughput is donated as α , the cargo and mail throughput is donated as β , the number of aircraft movements is donated as γ . Also assume that, compared with the previous reporting period, the growth rate of passenger throughput is donated as x , the growth rate of cargo throughput is donated as y , the growth rate of number of aircraft movements is donated as z . Under these parameters, several measurable indicators can be constructed as follows:

- 1. Measurable Economic Indicator (MEI)

Measurable economic indicator (MEI), denoted by E , is the weighted average of the passenger throughput and cargo throughput, and is calculated with the following formula:

$$E = \frac{a}{a+b}\alpha + \frac{b}{a+b}\beta \tag{1}$$

Where a is the weight of α and b is the weight of β . The calculation of this formula only incorporates the value of α and β without the units of measurement, so the MEI is a unit-less value. The economic benefits of air transportation is positively correlated with the passenger throughput α and the cargo throughput β . In other words, normally, the more passengers and cargo entering and leaving the port range, the better its economy would be. Thus, it is reasonable that the weighted average of the passenger throughput α and cargo throughput β can represent the underlying meaning of economy of air transportation. a and b reflect the economic level of passenger air transportation and that of cargo and mail air transportation respectively. The proportion of a and b can be estimated. On China Post's website, it can be estimated that 1kg of cargo air travelling from Beijing to Shanghai is RMB ￥26. On Air China's website, the searched economy class fare for December 1, 2010 from Beijing to Shanghai is RMB ￥1060. If the unit of α is ten thousand people, and that of β is ten thousand tons, then the proportion of a and b can be estimated as

$$a : b \approx 1060 \times 10{,}000 : 26 \times 1000 \times 10{,}000 = 1060 : 26{,}000 \approx 1 : 25 .$$

Later analysis will be on the basis of this ratio.

- 2. Measurable Carbon Emission Indicator (MCEI)

Measurable carbon emission indicator (MCEI), denoted by C , is a positive correlated function of the number of aircraft movements. When considering carbon emission, relative comparisons are important rather than absolute comparisons. Thus, taking γ as C, the calculations will be relatively simple. It only incorporates the value of γ without the units of measurement, so the MCEI is a unit-less value. Therefore, the formula is presented as follows:

$$C = \gamma \tag{2}$$

- 3. Measurable Carbon Productivity Indicator (MCPI)

Measurable carbon productivity indicator (MCPI), denoted by P, refers to the proportion of the measurable economic indicator (MEI) E and the measurable carbon emission indicator (MCEI) C.It reflects the energy input-output ratio and is represented by the following formula:

$$P = E / C \tag{3}$$

- 4. Measurable Elasticity of Carbon Emission Indicator (MECEI)

Measurable elasticity of carbon emission indicator (MECEI), denoted by S, refers to the ratio of the growth of C and that of E. When the growth of E is positive, a small value of S means that the economic grows at the expense of low carbon emission, which accords with the principle of low-carbon economy. If the growth of E is denoted as φ and the growth of C is denoted as δ, S can be expressed by the following formula:

$$S = \delta / \varphi \tag{4}$$

Because $C = \gamma$, $S = \delta / \varphi = z / \varphi$ (z refers to the growth rate of number of aircraft movements γ). On the basis of Formula (1), it can be obtained that:

$$E(1+\varphi) = \frac{a}{a+b}\alpha(1+x) + \frac{b}{a+b}\beta(1+y) \tag{5}$$

Thus, $\varphi = [\frac{a}{a+b}\alpha(1+x) + \frac{b}{a+b}\beta(1+y)] / E - 1 = \frac{a\alpha}{a\alpha + b\beta}x + \frac{b\beta}{a\alpha + b\beta}y$

In the absence of corresponding data case, the value of equivalence elasticity of carbon emission indicator (MECEI) can be estimated. According to the "2009 Production Statistics Bulletin of National Airport" on CAAC, the yearly national passengers throughput is 486.063 million passengers, the yearly national cargo and mail throughput is 9.456 million tons. Thus, the weight ratio of x and y in the calculation of φ is

$\frac{a\alpha}{a\alpha + b\beta} : \frac{b\beta}{a\alpha + b\beta} = a\alpha : b\beta \approx 1 \times 486.06 : 25 \times 9.456 \approx 2.05 \approx 2$. Hence, ratio of the weight is 2 approximately. That is to say $\varphi \approx \frac{2}{3}x + \frac{1}{3}y$.

The following parts will be the assessment of low-carbon economy of Shenzhen aviation industry based on the indicators described above as a reference.

4. A Case Study of Shenzhen Aviation based on the Measurable Indicators

As stated in the above sections, the measurable indicators of low carbon economy of air aviation industry include MEI, MCEI, MCPI and MECEI. Based on these indicators and Shenzhen airport operations data profiles, the situation of low-carbon economy of Shenzhen aviation can be analyzed with assistance of Eviews6.0.

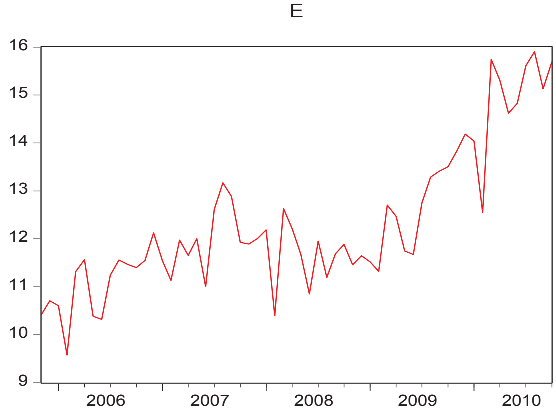
4.1. Description of the data

The data for analysis involves two sets, both of which are from the Wind data terminal. The first one, $\{(\alpha_t, \beta_t, \gamma_t)\}$, is used for the analysis of MEI, MCEI, MCPI and MECEI of Shenzhen. In this set, α represents the monthly Shenzhen airport passenger throughput, β represents the monthly Shenzhen airport cargo and mail throughput, γ represents the monthly Shenzhen airport number of aircraft movements, and the time range is from November of 2005 to October of 2010. The second data set, $\{(x_t, y_t, z_t)\}$ or $\{(xbjt,ybjt,zbjt), (xbyt,ybyt,zbyt), (xpdt,ypdt,zpdt), (xhqt,yhqt,zhqt), (xszt,yszt,zszt), (xxmt,yxmt,zxmt)\}$, is used for the comparisons of the MECEI for several major airports in China. In this set, x refers to the monthly year-on-year growth rate of passenger throughput, y refers to the monthly year-on-year growth rate of cargo throughput, z refers to the monthly year-on-year growth rate of number of aircraft movements. Besides, *bj, by, pd, hq, sz, xm* are abbreviations for Beijing airport, Baiyun airport, Pudong airport, Hongqiao airport, Shenzhen airport and Xiamen airport respectively. Moreover, the time range for the second set is from January of 2006 to July of 2010.

In the following parts, the analysis of Shenzhen's MEI, MCEI, MCPI and MECEI will be presented with assistance of the computer software, Eviews6.0.

4.2. The Analysis of Shenzhen's MEI

With the calculation using Eviews6.0 based on Formula (1) and the first data set, the MEI of Shenzhen air transportation from November 2005 to October 2010 is shown in Figure 1.



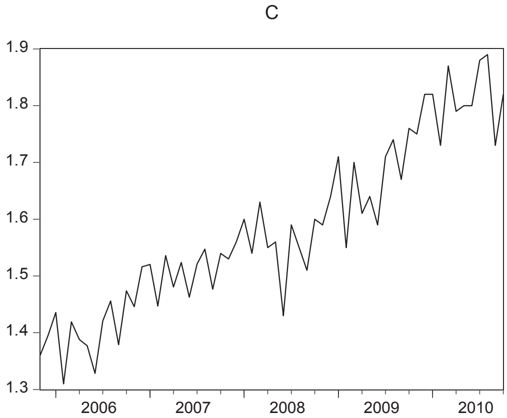
Source: Based on the Wind data, calculated by Eviews 6.0

Figure 1. The MEI of Shenzhen Air Transportation from November 2005 to October 2010

The mean and the standard deviation of the series are 12.32824 and 1.516246 respectively. With observation of the chart, it is noticeable that Shenzhen air transportation saw an increasingly economic growth during this period of time. Specifically, the MEI was about 10 by the end of 2005, and almost reached 16 by the end of 2010. It increased nearly 60%. Additionally, the economic benefits of air transportation in Shenzhen showed seasonal fluctuations.

4.3. The Analysis of Shenzhen's MCEI

With assistance of Formula (2) and the first data set, the MCEI of Shenzhen air transportation from November 2005 to October 2010 is shown in Figure 2.



Source: Based on the Wind data, calculated by Eviews 6.0

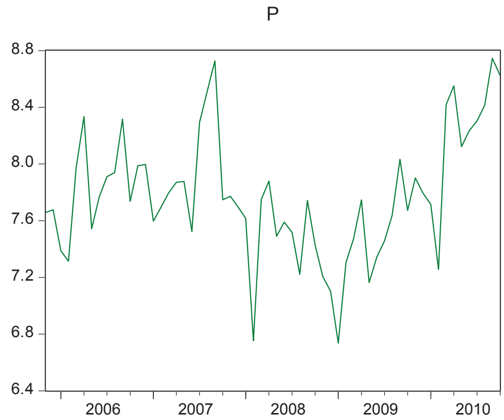
Figure 2. The MCEI of Shenzhen Air Transportation from November 2005 to October 2010

The mean and the standard deviation of the series are 1.583650 and 0.150886 respectively. It is also remarkable that Shenzhen air transportation saw an increasingly carbon emission growth during this period of time. It rose from above 1.3 by the end of 2005 to almost 1.9 by the end of 2010, and the increase was almost 46%. In addition, the carbon emission of air transportation in Shenzhen showed seasonal fluctuations. Because the increase of the carbon emission was less than 46% but that of the economic benefits was almost 60% during the same period, it was suggested that Shenzhen air transportation industry developed to some extent with low carbon.

4.4. The Analysis of Shenzhen's MCPI

Let's address this issue from the perspective of MCPI. Based on Formula (3) and the first data set, the MCPI of Shenzhen air transportation from November 2005 to October 2010 is shown in Figure 3.

The carbon productivity of air transportation in Shenzhen showed seasonal fluctuations during this period of time. It was comparatively high in 2007 (the peak appeared in the mid of 2007), but decreased to a low level in 2008 and 2009. In 2010, the indicator saw a high speed increase, which indicates that the carbon efficiency and carbon productivity of Shenzhen air transportation was the highest in 2010.
Besides, the mean, median and the standard deviation of the indicator are 7.776610, 7.744256 and 0.444809 respectively.

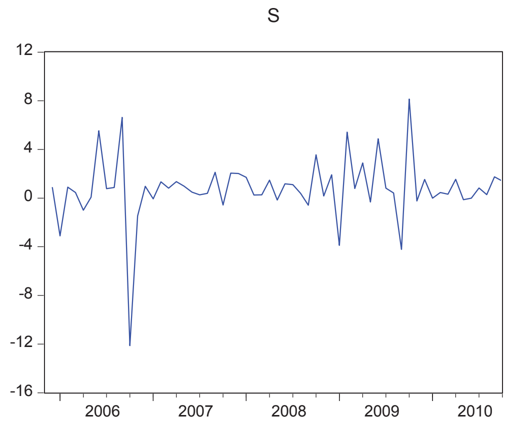


Source: Based on the Wind data, calculated by Eviews 6.0

Figure 3. The MCPI of Shenzhen Air Transportation from November 2005 to October 2010

4.5. The Analysis of Shenzhen's MECEI

With the calculation using Eviews6.0 based on Formula (4) and the first data set, the MECEI of Shenzhen air transportation from November 2005 to October 2010 is shown in Figure 4.



Source: Based on the Wind data, calculated by Eviews 6.0

Figure 4. The MECEI of Shenzhen Air Transportation from November 2005 to October 2010

In 2007, early 2008 and 2010, the MECEI was comparatively less. It reflects the situation that in these periods of time, economic growth was less dependant on carbon emission increase,. In other words, the effectiveness of low-carbon economy was good during these periods.

4.6. The Comparison of Low Carbon Economy of Shenzhen Airports with other China Main Airports

Depend on the second data set from the Wind data terminal, the comparison of low carbon economy of Shenzhen airports with other China main airports can be evaluated with indirect estimation method discussed in section 3 ("Measurable Indicators of Low-Carbon Economy of Air Transportation Industry").

The analysis is based on monthly year-on-year growth rate of aircraft movements, that of passenger throughput and that of cargo and mail throughput of six major airports in China, (Beijing Airport, Baiyun Airport, Pudong Airport, Hongqiao Airport and Shenzhen Airport and Xiamen Airport) from January 2006 to July 2010. Based on the above data and definition of the MECEI, air transportation of Shenzhen can be compared among those of China's major cities.

With the indirect estimation method of the the MECEI, the indicators and their statistics can be calculated. The following Table 1 is the descriptive statistics of the estimated of the corresponding air transportation industries.

Table 1. The Statistics of MECEI of Major Airports in China

	MECEI of Beijing Airport	MECEI of Baiyun Airport	MECEI of Hongqiao Airport	MECEI of Pudong Airport	MECEI of Shenzhen Airport	MECEI of Xiamen Airport
Mean	0.878401	0.815693	0.509306	1.208969	1.845927	0.456604
Median	0.524558	0.702830	0.437768	0.948229	0.705882	0.857746
Maximum	8.684211	6.580645	6.000000	15.50000	40.00000	6.545455
Minimum	-2.544304	-2.282609	-3.692308	-11.28571	-1.666667	-31.80000
Std. Dev.	1.493326	1.292611	1.183686	3.134221	6.282099	4.743818

Source: Based on the Wind data, calculated by Eviews 6.0

Through observation of Table 1, it can be found out that excessive values (which are caused by extremely small values of growth of the MEI) of the MECEI for Shenzhen contribute to its mean intensively, for example, the maximum of the MECEI for Shenzhen is 40.00, which contributes a lot to the mean. So the mean is not a good statistic for comparison between major airports. Therefore, by comparison using the median of the MECEI, Hongqiao Airport is the best among those six airports in terms of low-carbon development, because its median of the MECEI is the least. The median of the MECEI for Shenzhen Airport (0.71) is lesser than those of Pudong Airport (0.95) and Xiamen Airport (0.86). Although the statistic is not lesser than those of Hongqiao Airport and Beijing Airport (the second best among the six), it is similar to that of Baiyun Airport. Thus, the above analysis suggests that the low-carbon economy of Shenzhen aviation is at a relatively high level among the six major airports in China.

5. Conclusion

This paper discussed the indicators of low-carbon air transportation and concluded as follows:

- General indicators of low-carbon economy for air transportation industry include the level of carbon emission per capita/mile, the level of ton-km carbon emission, the carbon productivity, the carbon intensity of energy, the elasticity of carbon emission and aircraft capacity or aircraft load.
- The paper establishes the measurable indicators which can be used to assess the level of low carbon aviation based on generally published data. These measurable indicators are Measurable Economic Indicator (MEI), Measurable Carbon Emission Indicator (MCEI), Measurable Carbon Productivity Indicator (MCPI), and Measurable Elasticity of Carbon Emission Indicator (MECEI).
- The paper presents some indirect estimation methodologies to estimate the indicators with the limited data of air transportation.
- The paper takes Shenzhen aviation as a case to discuss the evaluation of its low-carbon economy with the established measurable indicators. To summarize the case, several items can be obtained: (1) the

economic and carbon emission of Shenzhen air transportation showed rapid growth from November 2005 to October 2010; (2) During this period, the economic growth of Shenzhen aviation outweighed the carbon emission growth rate of Shenzhen aviation, which indicates that low-carbon economic growth was achieved to some extent; (3) The level of low-carbon economy of Shenzhen air transportation saw the fluctuation, which was relatively high in 2007 and 2010, and relatively low in 2008 and 2009; (4) Low-carbon economy of Shenzhen aviation is at a relatively high level among the six major airports in China..

In short, this paper not only provides low-carbon economy indicators for air transportation with practical measurement effectiveness, but also discusses the issue from a new perspective and opens up a new direction for the study of low-carbon air transportation.

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